Adapting GDOI for Balanced Batch LKH

Josep Pegueroles

Telematics Engineering Department.

Technical University of Catalonia

Barcelona, Spain

Contents

Introduction

- **Goal of the work:**
  - Studying the behavior of batch rekeying in real scenarios and improving Lam-Gouda's algorithm.
- **Roadmap:**
  - Generating synthetic user behavior patterns (according to benchmark scenarios) in order to simulate performance behavior of batch rekeying algorithms
  - Simulate and detect flaws of proposed batch rekeying algorithm
  - Propose a slight variation in the algorithm
  - Introduce broadcast encryption in multicast key management for single and batch processing
  - Adapt the algorithms to GDOI
  - Implementation of LKH and variation algorithms in GDOI

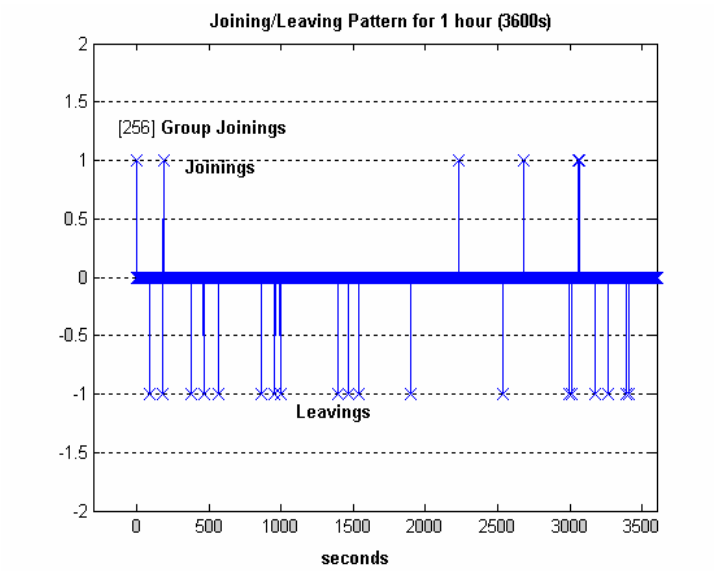
Benchmark Scenarios

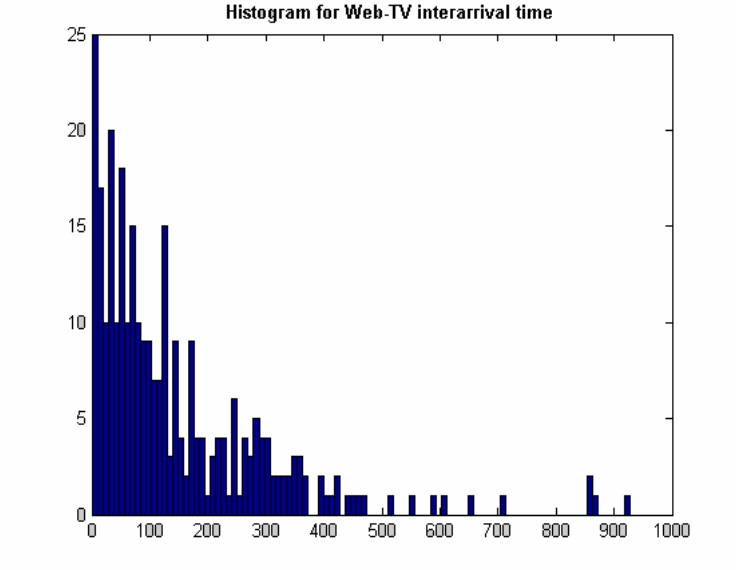
- R. Canetti, J. Garay, G. Itkis, D. Micciancio, M. Naor, and B. Pinkas, **Multicast security: A taxonomy and some efficient constructions** INFOCOM 99. Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE, vol. 2, pp. 708-716, 1999.

- **2 benchmark scenarios pointed out :**
  - single source broadcast
  - virtual conferences
- **One more scenario included :**
  - netgames
- **All patterns generated in Matlab**

Benchmark Scenarios

❑ Single source broadcast

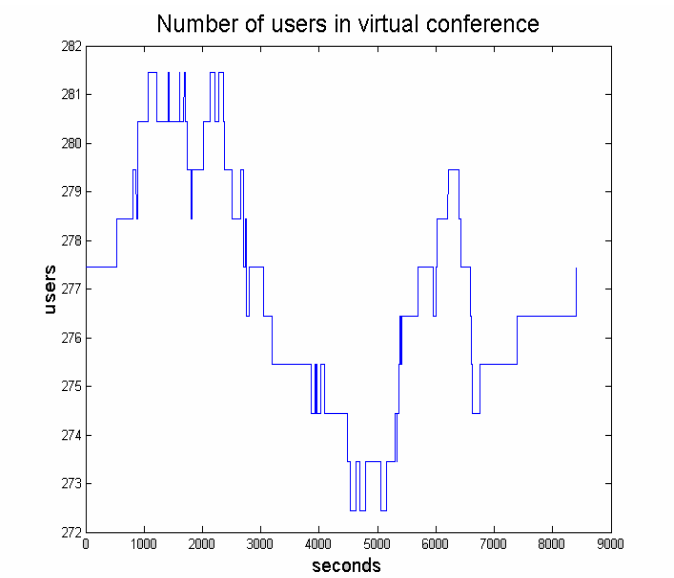


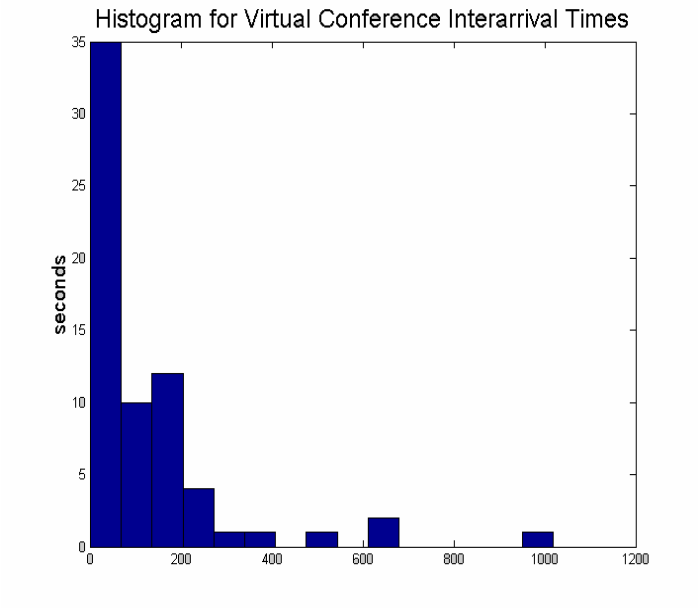


- **Exponential distribution inter-arrival time**
- **Based on the classic study of Almeroth and Ammar**
  (Multicast Group Behavior in the Internet's Multicast Backbone (MBone), IEEE Communications, June 1997)
- **Mean value of Inter-arrival time can be set by desing**

Benchmark Scenarios

❑ Virtual conferences



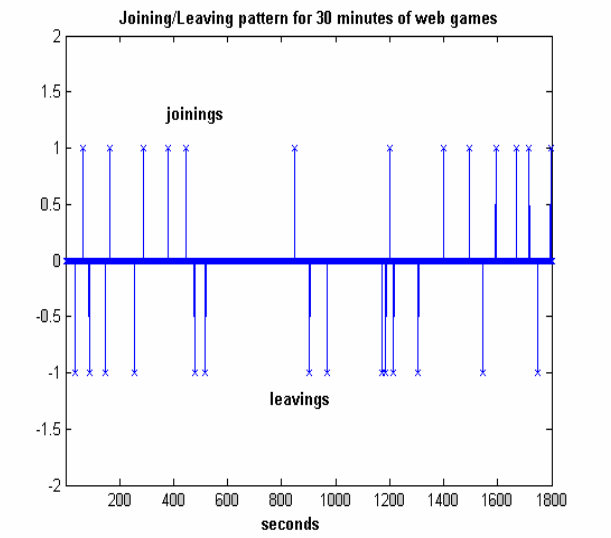


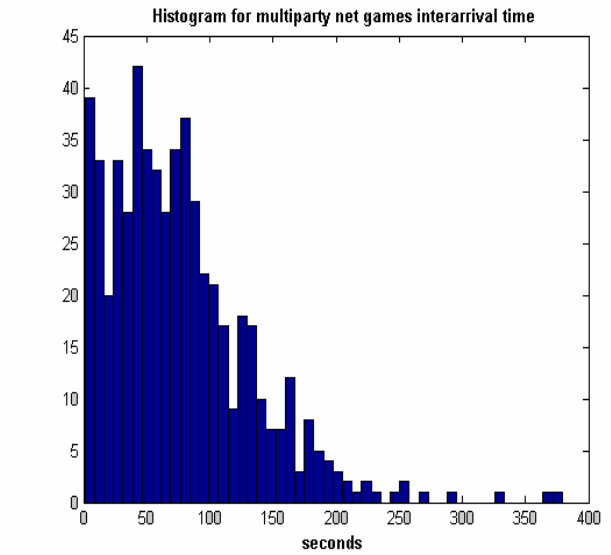
- A random number of users establish a virtual conference
- After a random period of time users begin to join/leave the group following an exponential inter-request time statistics

Benchmark Scenarios

Networked games

- Henderson, Bhatti (2001). **Modeling user behavior in networked games**. Proceedings of ACM Multimedia 2001, Ottawa, Canada, pp212-220, October 2001





- **Player interarrival times are highly correlated at short lags which implies that the arrival of some users will lead to others arriving**
- **Interarrival times for networked games follow a heavy-tailed distribution**

Performance of Batch Rekeying with benchmark scenarios

Why real patterns should be included?

Li, Yang, Gouda, Lam. **Batch Rekeying for Secure Group Communications**. ACM SIGCOMM 2001, San Diego, August 2001

Introduce batch processing for Join/Leave requests but simulation results presented does not fit a real request pattern but a uniformly distributed and only considering the total number of joining and leaving requests but not their position in the tree.

In such cases, it is easy to get an **unbalanced tree** after a few batches.

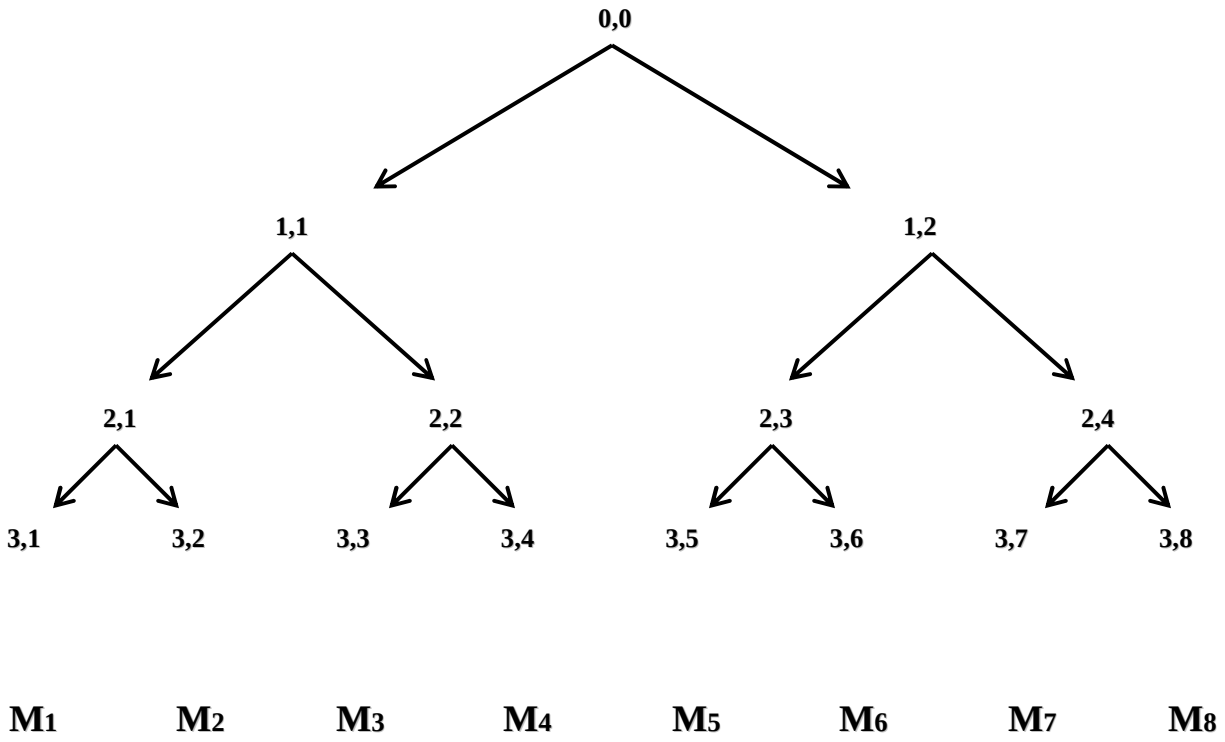
An additional balancing algorithm is suggested after some rekeyings to overcome this flaw

Lam-Gouda Proposal not balanced

New joinings are located substituting leavings

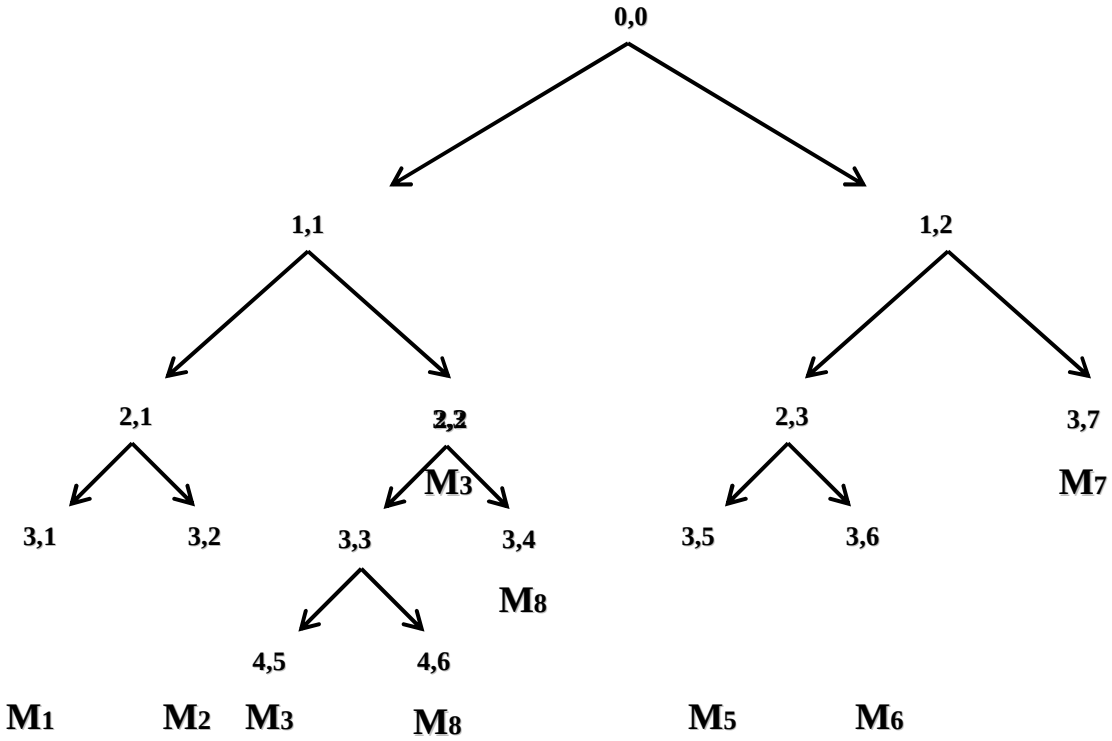
If number of joinings exceeds leavings a subtree is constructed and placed under the shallowest leaf

- **Example: Member 4 and Member 8 leave the group**



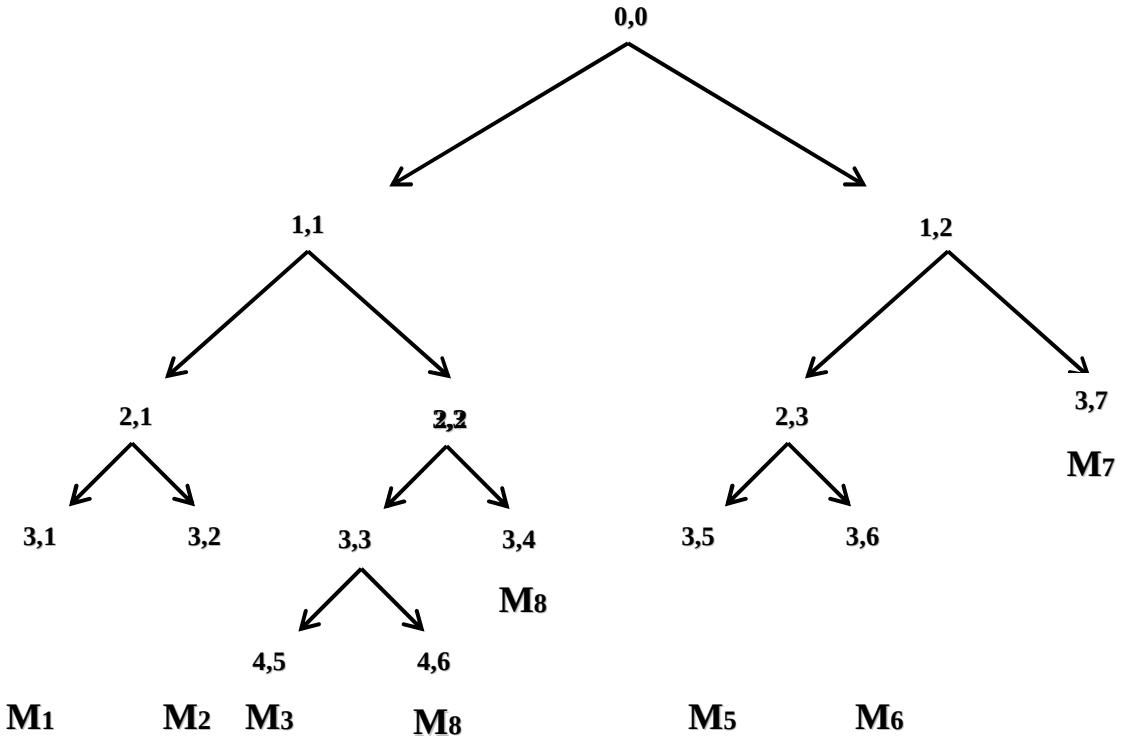
Lam-Gouda Proposal not balanced

- 2 joinings and no leaving



Lam-Gouda Proposal not balanced

- M5 and M6 leave the group



Balanced Batch Rekeying

Pegueroles, Rico-Novella. **Balanced Batch LKH: New Proposal, Implementation and Performance Evaluation**. IEEE Symposium on Computers and Communications - ISCC'2003, 2003

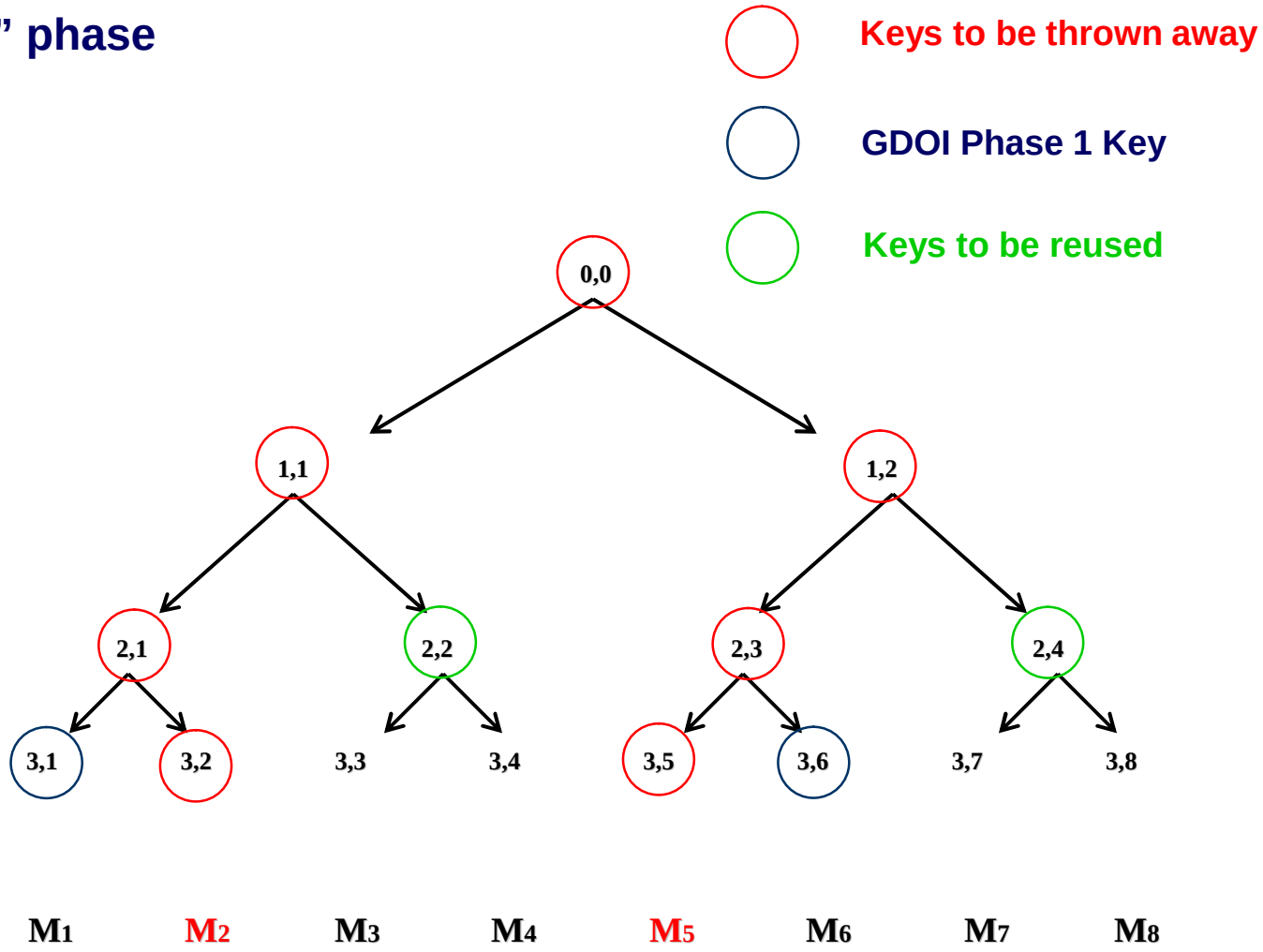
We have **proposed a batch rekeying method leading to** completely **balanced trees**.

It is **based on the assumption that**:

- **Siblings of departed members are treated as new members** with GDOI phase 1 already done
- **Members can change their position in the tree from one batch to another,** not only in their path to the root but also can jump to another branch.

Balanced Batch Rekeying

"Mark Tree" phase

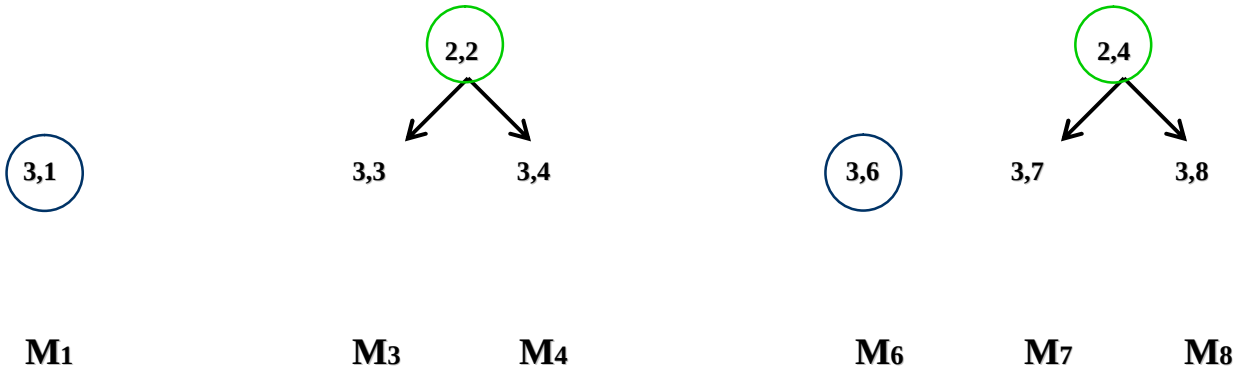


Balanced Batch Rekeying

“Prune Tree” phase

GDOI Phase 1 Key

Keys to be reused



Balanced Batch Rekeying

"New Rekey Tree" phase

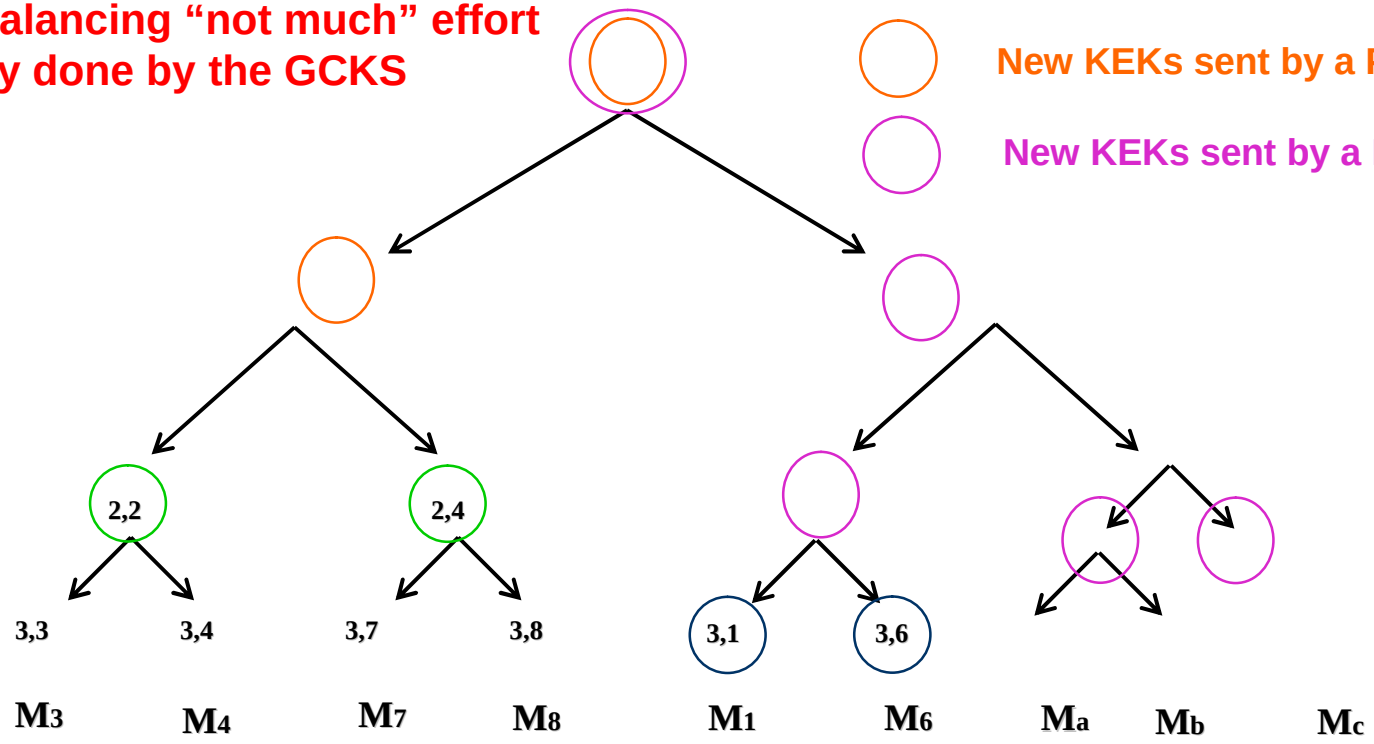
Position is not taken into account
Members do not know their actual position
The balancing "not much" effort is only done by the GCKS

GDOI Phase 1 Key

Keys to be reused

New KEKs sent by a PUSH message

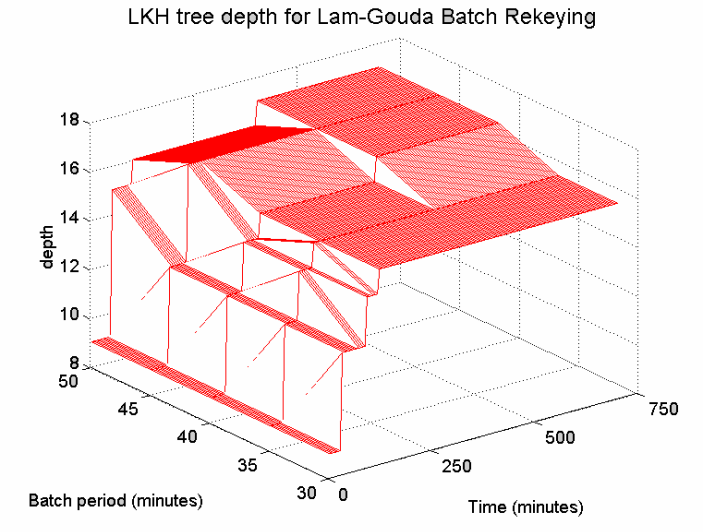
New KEKs sent by a PULL message

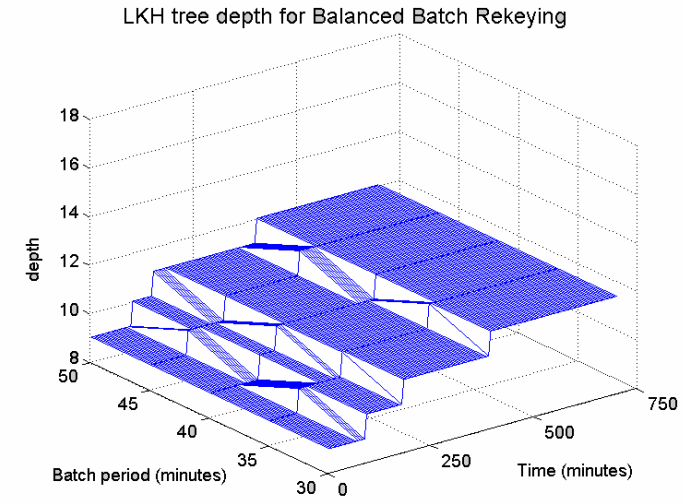


Only the Key-Handle GDOI's parameter is used

Balanced Batch Rekeying

- **Tree depth evolution for Lam-Gouda and balanced batch rekeying algorithm in web tv environment**

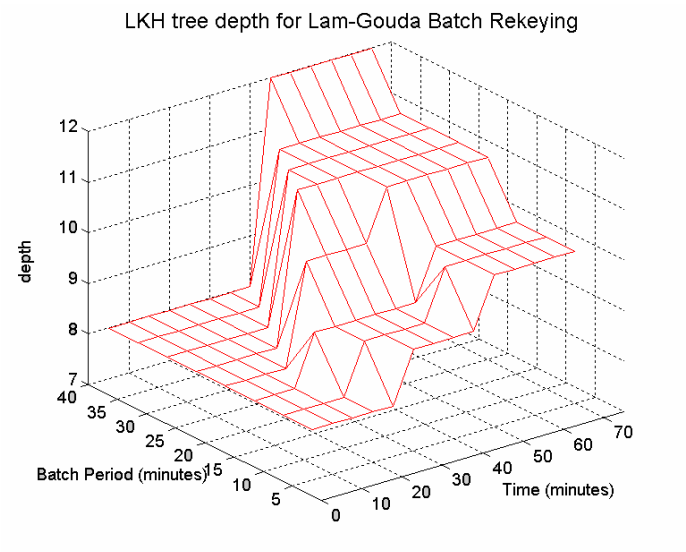


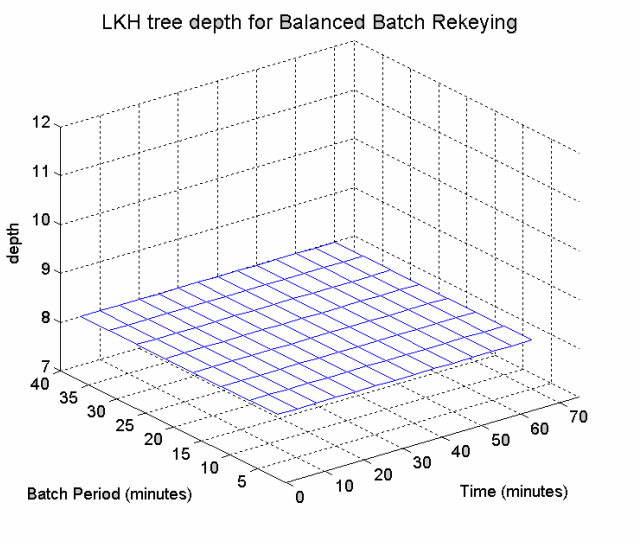


Effect of the peak arrivals minimized

Balanced Batch Rekeying

- **Tree depth evolution for Lam-Gouda and balanced batch rekeying algorithm in virtual conference environment.**

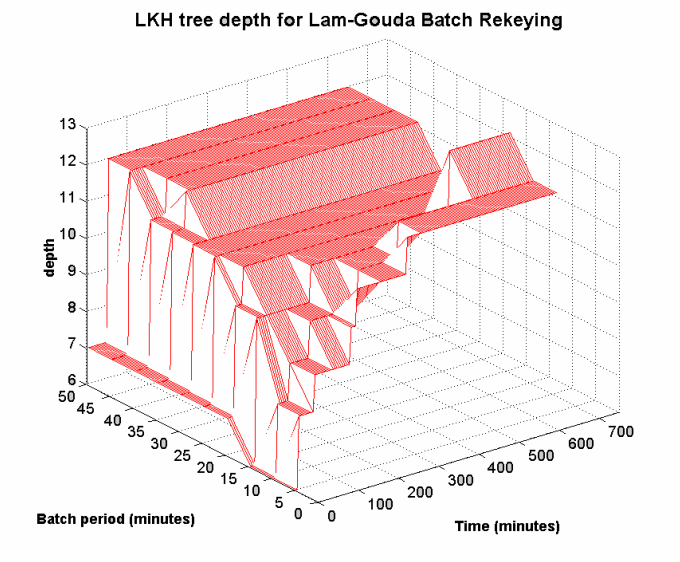


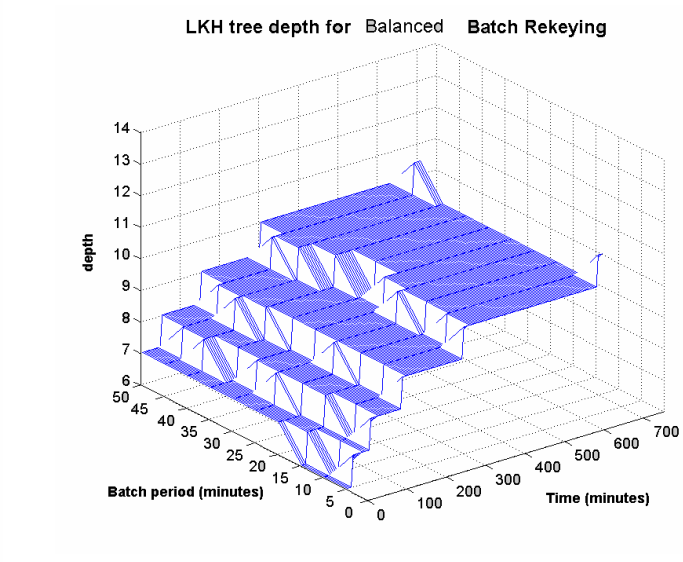


If number of members is within a range tree depth remains constant

Balanced Batch Rekeying

- **Tree depth evolution for Lam-Gouda and balanced batch rekeying algorithm in networked games environment**





Balanced Batch Rekeying

- **We have arrived at the same conclusion as Lam and Gouda:**

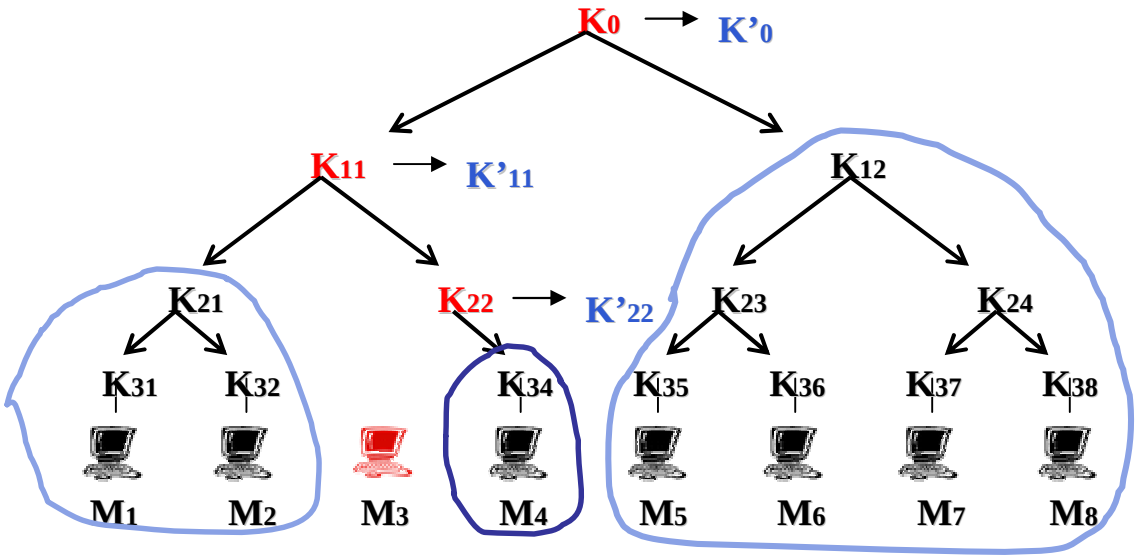
Balancing is better...

...but we have introduced balancing in the algorithm itself

Introducing Broadcast Encryption: Single message rekeying algorithm

Single message rekeying

Assume the following scenario:



We consider the concatenated LKH message

$$K_{34}\{K_0'\}\ \ K_{34}\{K_{11}'\}K_{34}\{K_{22}'\} \,||\, K_{21}\{K_0'\}\ K_{21}\{K_{11}'\} \,||\, K_{12}\{K_0'\}$$

as **3 messages** cause it is the result of 3 encryption operations. Moreover, parts of this message are not useful for some remaining members.

We want to generate **a single message**, the same **for all the** remaining **members**.

We use **number theory and modular reduction**.

Single message rekeying

Let every node in the tree be a random number generated as follows:

» $K_{(i,j)} = F_{r1}(2^i + j) \oplus r$

When the node wants to be updated, the only necessary information is

» $P = r \oplus r'$

and the updated number will be computed as follows:

» $K'_{(i,j)} = K_{(i,j)}$ Å $P = F_{r1}(2^i + j)$ Å r'

When updating is needed only *P* has to be delivered to the remaining members

At this moment the GCKS only has to store *r1* and *r'* and the *TEK*

Bin, Jian-Hua. ***Optimal Key Storage for Secure Multicast***. Department of Electronic Engineering, Shangai Jiaotong University

Single message rekeying

But, if the multicast message is constructed as follows:

$$P = r_2 \prod_{i \subset S} rnd_i + (r \oplus r')$$

We get only one (and the same) message for all the members.

That only have to divide modulo one of his secret numbers in order to obtain the updating parameter.

Although it can be considered weaker than LKH/OFT/OFC, it provides enough security level for many non critical applications.

Security analysis is included in

Pegueroles, Bin, Rico-Novella, Jian-Hua. **Efficient Multicast Group Rekeying**. Departamento de Ingenieria Telemática IR 2003.
http://isg.upc.es/gsec/work.html

Single message rekeying

But...

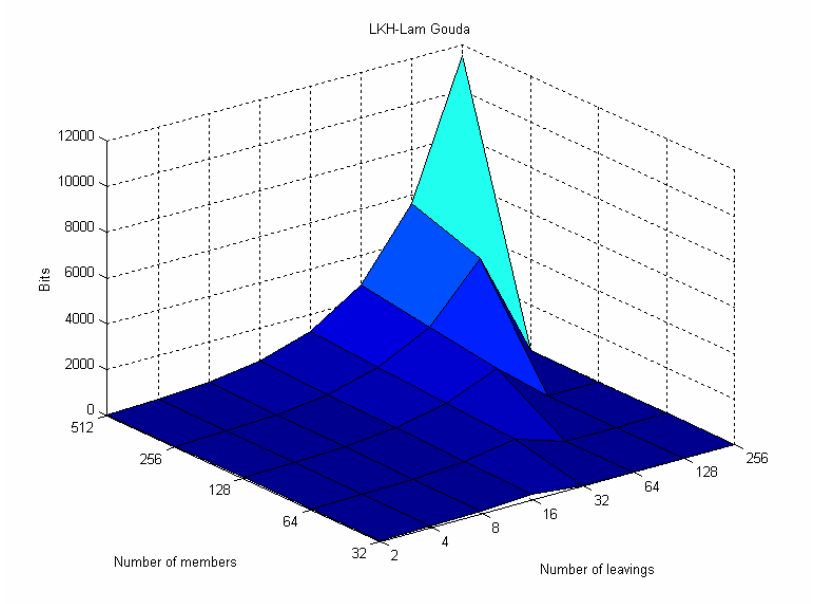
OK, the GCKS only has to store 3 numbers but we have 1 message of length KN instead of N messages of length K... where's the improvement?

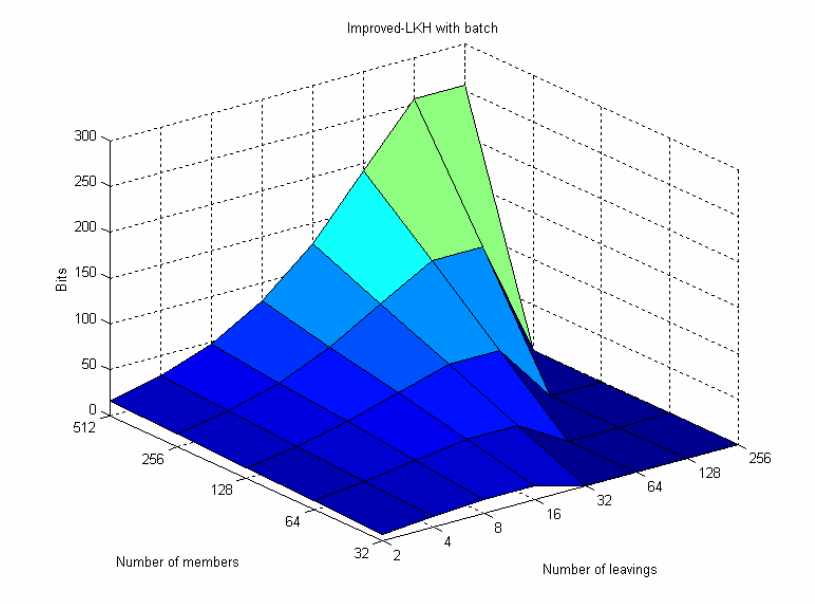
First, the length of the messages needed in simple LKH is greater than each of the numbers of the modulo product.

Second, If Batch rekeying is considered...

Single message rekeying for batch rekeying

Comparing the total amount of bits used for rekeying in Batch LKH Lam Gouda and batch with single message rekeying...





Pegueroles, Hernandez-Serrano , Rico-Novella, Soriano . **Improved LKH for Batch Rekeying in Multicast Groups**. To appear in the proceedings of the IEEE International Conference on Technology Research and Education (ITRE 2003) New Jersey August 2003.

Adaptation for GDOI

- GDOI perfectly fits with all the mentioned algorithms
- Only some considerations of unused parameters in LKH payload message format have to be added
- We have started the task of adding LKH to GDOI Brian Weis' implementation

Work to do

- **Discuss the proposed methods:**
  - balanced batch
  - single message rekeying
- **Include them in a standard track LKH/OFT/OFC...**
- **Finishing the implementation of these algorithms in GDOI testbed**

Contact Information

Josep Pegueroles
Telematics Engineering Dept.
Technical University of Catalonia
josep.pegueroles@entel.upc.es